The composition of the new continental crust through time

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Recent models on continental growth suggest that ca. 65% of the present volume of the continental crust was present by 3 Ga, and that the rates of continental growth were significantly higher before 3 Ga than subsequently. This change has been tentatively linked to the onset of subduction-driven plate tectonics and discrete subduction zones. If correct this represents a fundamental change in the evolution of the Earth, with implications for the nature of the magmas generated, the efficiency with which crustal material is returned back into the mantle and the cooling history of the Earth.

Because of the poor preservation of rocks and minerals after billions of years of crustal evolution, a major uncertainty remains about the composition of new, juvenile continental crust in the Hadean and the Archaean and hence the conditions and the tectonic setting(s) in which it was generated. One way forward is to evaluate the composition of new continental crust from the time-integrated parent/daughter ratios of isotope systems in magmatic rocks subsequently derived from that new crust.

Crustal differentiation processes produce a large range of highly fractionated Rb/Sr ratios because of the highly incompatible character of the Rb-Sr system. As a consequence mafic crust typically has Rb/Sr at least five times lower than intermediate/felsic bulk crust. We calculated time-integrated Rb/Sr in crustal material with pre- and post-3 Ga Nd model ages. Preliminary data indicate that time-integrated Rb/Sr were, on average, much lower in the Hadean/Mesoarchaean than subsequently. This suggests that new continental crust was principally mafic over the first 1.5 Ga of Earth evolution, that a large volume of pre-3 Ga crust may have been associated with intraplate magmatism, and that ~3 Ga may indeed mark the onset of plate tectonics on Earth.

Simulation of water–rock interaction and porosity evolution in a granitoid-hosted enhanced geothermal system

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Numerical simulations based on plans for a deep geothermal system in Basel, Switzerland are used here to understand chemical processes that occur in an initially dry granitoid reservoir during hydraulic stimulation and long-term water circulation to extract heat. A question regarding the sustainability of such enhanced geothermal systems (EGS) is whether water–rock reactions will eventually lead to clogging of flow paths in the reservoir. A reactive transport model allows the main chemical reactions to be predicted and the resulting evolution of porosity to be tracked over the expected 30-year operational lifetime of the system.

The simulations show that injection of surface water to stimulate fracture permeability in the monzogranite reservoir at 190 °C and 5000 m depth induces strong redox reactions. Although new calcite, chlorite, hematite and other minerals precipitate near the injection well, their volumes are low and more than compensated by those of the dissolving wall-rock minerals. Thus, during stimulation, reduction of injectivity by mineral precipitation is unlikely.

During the simulated long-term operation of the system, the main reactions are the hydration and albitization of plagioclase, the alteration of hornblende to an assemblage of smectites and chlorites and of primary K-feldspar to muscovite and microcline. Within a closed-system doublet, the composition of the circulated fluid changes only slightly during its repeated passage through the reservoir, as the wall rock essentially undergoes isochemical recrystallization. Even after 30 years of circulation, the calculations show that porosity is reduced by only ~0.2%, well below the expected fracture porosity induced by stimulation. This result suggests that permeability reduction owing to water–rock interaction is unlikely to jeopardize the long-term operation of deep, granitoid-hosted EGS systems.

A peculiarity at Basel is the presence of anhydrite as fracture coatings at ~5000 m depth. Simulated exposure of the circulating fluid to anhydrite induces a stronger redox disequilibrium in the reservoir, driving dissolution of ferrous minerals and precipitation of ferric smectites, hematite and pyrite. However, even in this scenario the porosity reduction is at most 0.5%, a value which is unproblematic for sustainable fluid circulation through the reservoir.

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